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Modelling the three-dimensional stratigraphy of an ice rise

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The geometry of englacial isochrones is a product of the past and present ice velocity field and is useful for our understanding of steady-state ice flow dynamics, flow regime re-organisation, and calibration of models. Ice rises contain various flow regimes (divide flow, flank flow, and grounding zones) on small spatial scales, meaning they are ideal locations to study ice-flow dynamics and stratigraphy to constrain model parameters. We run full Stokes, thermo-mechanically coupled simulations of Derwael Ice Rise in East Antarctica and simulate the three-dimensional stratigraphy of the ice rise and the surrounding ice shelf using the finite element model Elmer/Ice. Over the ice rise, we derive the accumulation rate from internal reflection horizons and use RACMO2.3 surface mass balance data over the surrounding ice shelf. Simulations are run for Glen's flow law exponents of n=3 and n=4 with appropriate values derived for the Arrhenius law.

To calibrate the model, comparisons are made with the BedMachine surface elevation and density-adjusted internal reflection horizons observed in many transects recorded by AWI's ultra-wide band radar covering the divide, the flanks, and the grounding zones. To understand ice flow dynamics where the velocity field of the ice rise and the ice shelf converge in the compressive and shear zones, we analyse the modelled englacial stress and strain rate fields. Our results allow us to investigate isochronal structures where observed internal reflection horizons are too steep or obscured to be adequately picked up by radar. A comparison between the model and observed fracturing can be used to infer threshold stress and strain rates for fracture initiation. These simulations are a blueprint for the full Stokes, three-dimensional modelling of ice rises and have further relevance in the study of three-dimensional influences on Raymond arch evolution, the constrained coupling of the anisotropy equations, comparisons with ice core data and the automated inference of ice flow parameters from internal reflection horizons.